arXiv:cond-mat/9812290v1 [cond-mat.supr-con] 16 Dec 1998

Comment on "Is The Nonlinear Meissner Effect Unobservable?"

Anand Bhattacharya[1], Igor Žutić[2], Oriol T. Valls[1] and A.M. Goldman[1]
[1] School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455-0149
[2] Department of Physics, University of Maryland, College Park, MD 20742-4111

(February 1, 2008)

In a recent Letter [1] by Li, Hirschfeld and Wölfle (LHW) on nonlocal effects in unconventional superconductors, it was suggested that these effects might explain the null result for the nonlinear Meissner effect (NLME) in our experiments [2,3] on optimally doped $YBa_2Cu_3O_{6.95}$ (YBCO) single crystals for which an appreciable signal is predicted by theory [4,5].

We have no objection to the main part of the LHW letter, which deals with a detailed calculation of the nonlocal effects [6]. However, the remarks made about our experimental results do not directly follow from these detailed calculations but are critically dependent on a qualitative argument which fails to work for YBCO.

The qualitative argument relies on treating YBCO as a "weakly 3-D" system. This leads LHW to the conclusion that nonlocal effects will wipe out the NLME (for the geometry of our experiments) for fields below about $0.8 \sim 1 H_{c1}$. However, the estimate of H_{c1} from the "weakly 3-D" argument is [1] $\Phi_0/(2\pi\lambda_0\lambda_{0c})$ (where Φ_0 is the flux quantum, and λ_0 and λ_{0c} are the zero temperature penetration depths for currents flowing in the *a*-*b* plane and along the *c*-axis respectively), which leads to a value of H_{c1} of twenty Gauss or less. This is over an order of magnitude below the experimental value of the field at which first flux penetration occurs which is [3] 300 Gauss or more [2]. In our experiments, the samples used have typical dimensions of 1.5mm x 1.5mm x 50μm (*a* x *b* x *c*). The magnetic field is applied in the *a*-*b* plane and given the sample geometry, most of the screening current flows in the *a*-*b* plane with components along the nodal directions, with the exception of the return currents that flow near the edges in the *c*-axis direction. Thus, we expect the field of first flux entry to be closer to $\Phi_0/(2\pi\lambda_0^2)$, which is borne out by experiment. For currents in the *a*-*b* plane, the nonlocal effects are very small, much smaller than the NLME at fields of 300G. For the return currents, the nonlocal effects may be relevant, *but* these do not contribute in any way to NLME, as they have no components in the nodal directions. Thus, for our experimental geometry, the nonlocal contributions are irrelevant.

The same conclusion can be reached even more starkly by starting from the estimate of the characteristic nonlocal energy, given in LHW as $E_{nl} = \xi_{0c}\Delta_0/\lambda_0$. Quasiparticle effects will be ineffective, due to nonlocality, for quasiparticles within an angle of less than ϕ_{nl} from a node, where ϕ_{nl} is determined from the condition $\Delta(\phi_{nl})/E_{nl} \sim 1$. This yields $\phi_{nl} \sim 0.001$ implying that the NLME requires an applied field $H > H_m$ with $H_m/H_0 \sim 0.001$ where H_0 is [5] the characteristic field scale of the NLME. Since H_0 is about [5,3] 8000 gauss, we have that H_m is about ten gauss, in rough agreement with the argument in the previous paragraph.

To summarize: we find it quite plausible that the nonlocal effects indeed render the NLME unobservable at fields below ten or twenty Gauss. Since the experiments are performed at fields over one order of magnitude larger, however, with the sample remaining in the Meissner state, it is obvious that the explanation for our negative result must lie elsewhere. In our opinion [3] the presence of at least a few percent component of imaginary s or d_{xy} character in the gap remains the most likely explanation.

[1] M.R. Li, P.J. Hirschfeld and P. Wölfle, Phys. Rev. Lett. **81**, 5640 (1998)
[2] J.Buan et al. , Phys. Rev. Lett. **72**, 2632 (1994).
[3] A. Bhattacharya, I. Žutić, Oriol.T. Valls, Allen M. Goldman, Ulrich Welp, Boyd Veal, cond-mat/9812234.
[4] S.K.Yip and J.A.Sauls, Phys. Rev. Lett. **69**, 2264 (1992); D.Xu, S.K.Yip and J.A.Sauls, Phys. Rev. B **51** (22), 16233 (1995).
[5] I. Zutic and Oriol T. Valls, Phys Rev **B56**, 1279, (1997); Phys Rev **B58**, 8738, (1998).
[6] I. Kosztin, A.J. Leggett, Phys. Rev. Lett. **79**, 135 (1997).